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MILITARY APPLICATIONS

OF

NUCLEAR RESONANCE FILTERS

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by

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GENERAL PURPOSE

Under the terms of the contract Varian Associates shall conduct research on military applications of nuclear resonance filters. This work includes, but is not necessarily limited to, the following:

1. Experimental demonstration of the idea to show in the simplest manner that the nuclear induction filter works.

2. A detailed theoretical study of the physics of the problem.

3. An analysis of the behavior of the nuclear induction filter as a new type of filter element.

PROGRESS

Laboratory Testing:

Apparatus

The laboratory tests consist of measurements of the response of the system to pulses of arbitrary width, amplitude, and frequency. Test gear has been constructed which will provide two crystal controlled r-f sources which can be pulsed separately by a combination of pulses having different widths and occurring at different times. The output amplitude of each channel can be adjusted over a range of about 36 db by means of calibrated attenuators. The frequency of the two crystal controlled oscillators can be shifted slightly by means of trimmer condensers shunting the crystals. This provides a pulse to simulate a coherent ground clutter and a pulse shifted in frequency to simulate the Doppler shifted target echo.

Double Pulse and Frequency Testing:

Using the apparatus described above, it has been demonstrated that a weak signal will pass through the filter unaffected by the presence of a much larger signal at a slightly different frequency. The strong signal has the saturated appearance shown before (that is, a flat center with edge pips which have a width corresponding to the spectral width of the magnetic field inhomogeneity). The shifted weaker signal is passed more or less in its original form.

The two signals may be shifted in time with no change being observed other than a linear additive effect. The amplitude of the Doppler shifted signal is about comparable to the amplitude of the edge pips from the simulated ground clutter and is much larger than the saturated flat portion. With a nuclear time constant T_1 of about 1/30 of a second, the Doppler shifted frequency needs to be different from the simulated ground clutter by only about 10 cycles (or n times the repetition rate plus or minus 10 cycles) to remove the interaction between the two pulses. If the separation in the frequency is less than this, the weaker pulses will show the same saturation characteristics as the strong pulse.

Precise quantitative data of this very interesting result has not been taken because of the emphasis upon investigating the difficulties associated with the edge effects.

Single Pulse and Single Frequency Testing:

A great deal of work has been done to understand in greater detail the causes for the transmission of the pulse edges through the filter. In general, the appearance of the saturated pulses is as if they were differentiated, rather than completely saturated; and therefore the action of the filter is impaired.

As an aid to study, it is convenient to consider pulses which are so short that the spectral distribution covers the spin distribution almost uniformly, and long pulses such that the spectrum lies within the spin distribution.

The shape of the signal passed by the nuclear induction filter is so complex that it is best shown by means of pictures. However, it can be said in general that for the saturated region the output pulse amplitude will start to increase before th occurrence of the input pulse and will decay after the input pulse. This is a behavior which can be understood in terms of the spin-echo concept, and, therefore, one expects to see the start and finish of the Fourier transform of the original spin distribution. While the driving field is on, the simple concept of course breaks down. If the pulse is wide, the portion of the output pulse which occurs during the time of the input pulse will be reduced to a low value. If the pulse is narrow, there will be only a dip at the center of the pulse and not a flat.

A 30 mc phase sensitive detector has been constructed to determine the phase of the signal transmitted through the filter. The reference is the unpulsed 30 mc carrier, and by the use of appropriate phase shifters either the u- or v-component of the signal can be observed. As a check on the performance of the phase sensitive detector, the v-components have been squared and added to give the signal which is observed by the usual indicator. The identification of the u- or v-component has been made by introducing leakage of known phase through an unbalance of the probe. In addition, the phase has been checked by the behavior of the system.

A great deal of information has been obtained with the phase sensitive detector. For wide pulses, the edges of the pulses are transmitted by means of the v-component which is the absorption part and was expected to saturate completely. When the center frequency of the spectrum corresponds to the center of the spin distribution, the u-component is almost entirely cancelled out. It can be shown to be a cancellation process since a shift to a lower or higher magnetic field produces a positive or negative signal corresponding to a 180° phase difference in the r-f transmitted by the system. The fact that the undesired edges are caused by the v-component precludes the possibility of improving performance by observing only this component.

Information concerning the filter properties has also been obtained by omitting an r-f driving pulse after the steady state has been reached. This is done by a gating circuit which will pass any number of pulses from 4 to 30 after which time one pulse is suppressed. The results are that for wide pulses the output of the filter, in the absence of an input pulse, immediately assumes the shape of the Fourier transform of the initial spin distribution. This state is again reached in about 4-6 pulses after the missing pulses. For narrow pulses the recovery from the unsaturated missing pulse seems to be instantaneous.

Several methods of attack have been tried for solving this problem analytically. Unfortunately, the complexity of the solution is so great that it has been impossible to write down a simple solution. Work is now going on to see if the problem can be solved by the use of an analog computer.

Field Testing:

The apparatus associated with the nuclear induction filter has been built and installed in a truck so that tests can be made at Stanford with the coherent Radar set which has been developed there. Several tests have been run up to the present time without any conclusive results being attained. These tests will be continued, with different types of ground clutter being observed. An apparatus has been built to simulate a target which does away with the need for target planes.